“Regional climate sensitivity and how well we can constrain it using observations”

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So, what is climate sensitivity?

AR4 definitions:

Equilibrium climate sensitivity (ECS): "Global annual mean surface air temperature change experienced by the climate system after it has attained equilibrium in response to a doubling of atmospheric CO_2*."**

Transient climate response (TCR): "Global average surface air temperature averaged over one year, centered at the time of CO_2 *doubling in a* $1\%yr^{-1}$ *experiment."**

*Note: Units are in degrees Celsius (°C).

One way to calculate ECS and TCR: from models

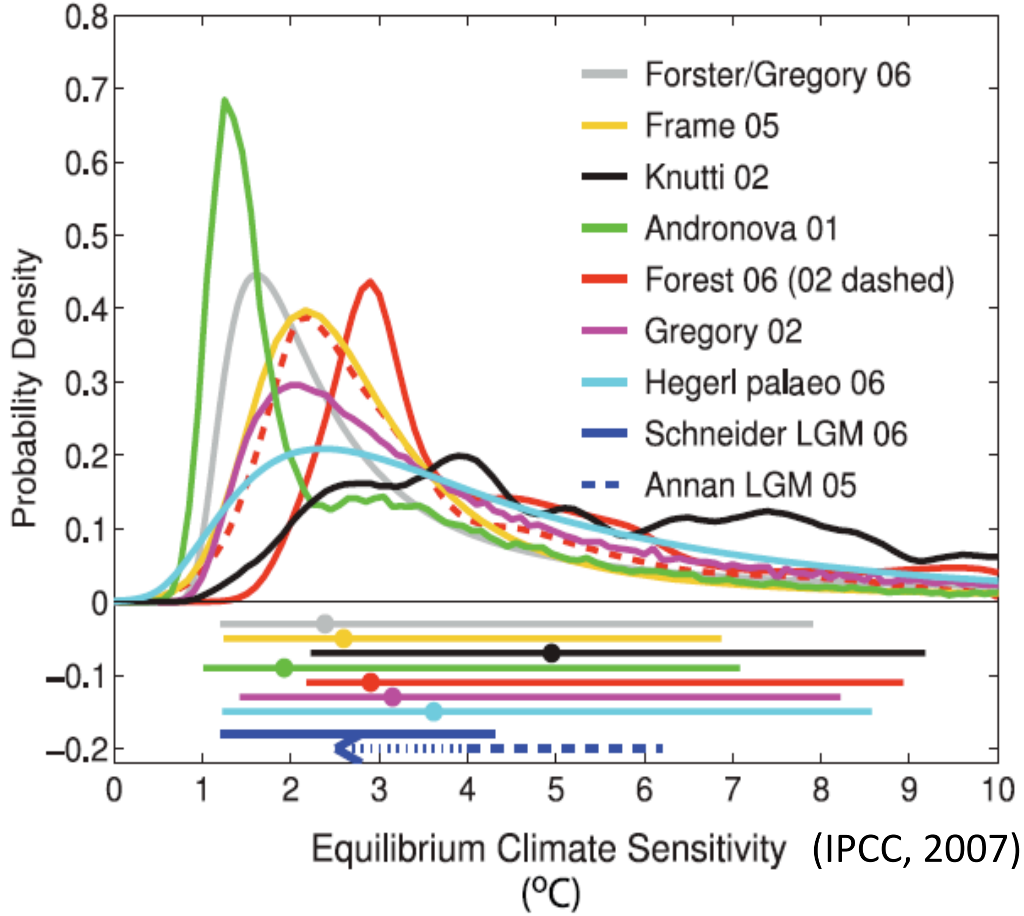
AOGCM	Equilibrium climate sensitivity (°C)	Transient climate response (°C)
1: BCC-CM1	n.a.	n.a.
2: BCCR-BCM2.0	n.a.	n.a.
3: CCSM3	2.7	1.5
4: CGCM3.1(T47)	3.4	*1.9*
5: CGCM3.1(T63)	*3.4*	n.a.
6: CNRM-CM3	n.a.	1.6
7: CSIRO-MK3.0	3.1	1.4
8: ECHAM5/MPI-OM	3.4	2.2
9: ECHO-G	3.2	1.7
10: FGOALS-g1.0	*2.3*	*1.2*
11: GFDL-CM2.0	2.9	1.6
12: GFDL-CM2.1	3.4	1.5
13: GISS-AOM	n.a.	n.a.
14: GISS-EH	2.7	1.6
15: GISS-ER	2.7	1.5
16: INM-CM3.0	2.1	1.6
17: IPSL-CM4	4.4	2.1
18: MIROC3.2(hires)	4.3	2.6
19: MIROC3.2(medres)	4.0	2.1
20: MRI-CGCM2.3.2	3.2	2.2
21: PCM	2.1	1.3
22: UKMO-HadCM3	3.3	2.0
23: UKMO-HadGEM1	4.4	1.9

IPCC, 2007

ECS: Ranges from 2.1°C to 4.4°C, with an average of 3.2°C.

TCR: Ranges from 1.2°C to 2.6°C with and average of 1.8°C.

And also global from global mean temperature observations



(IPCC, 2007)

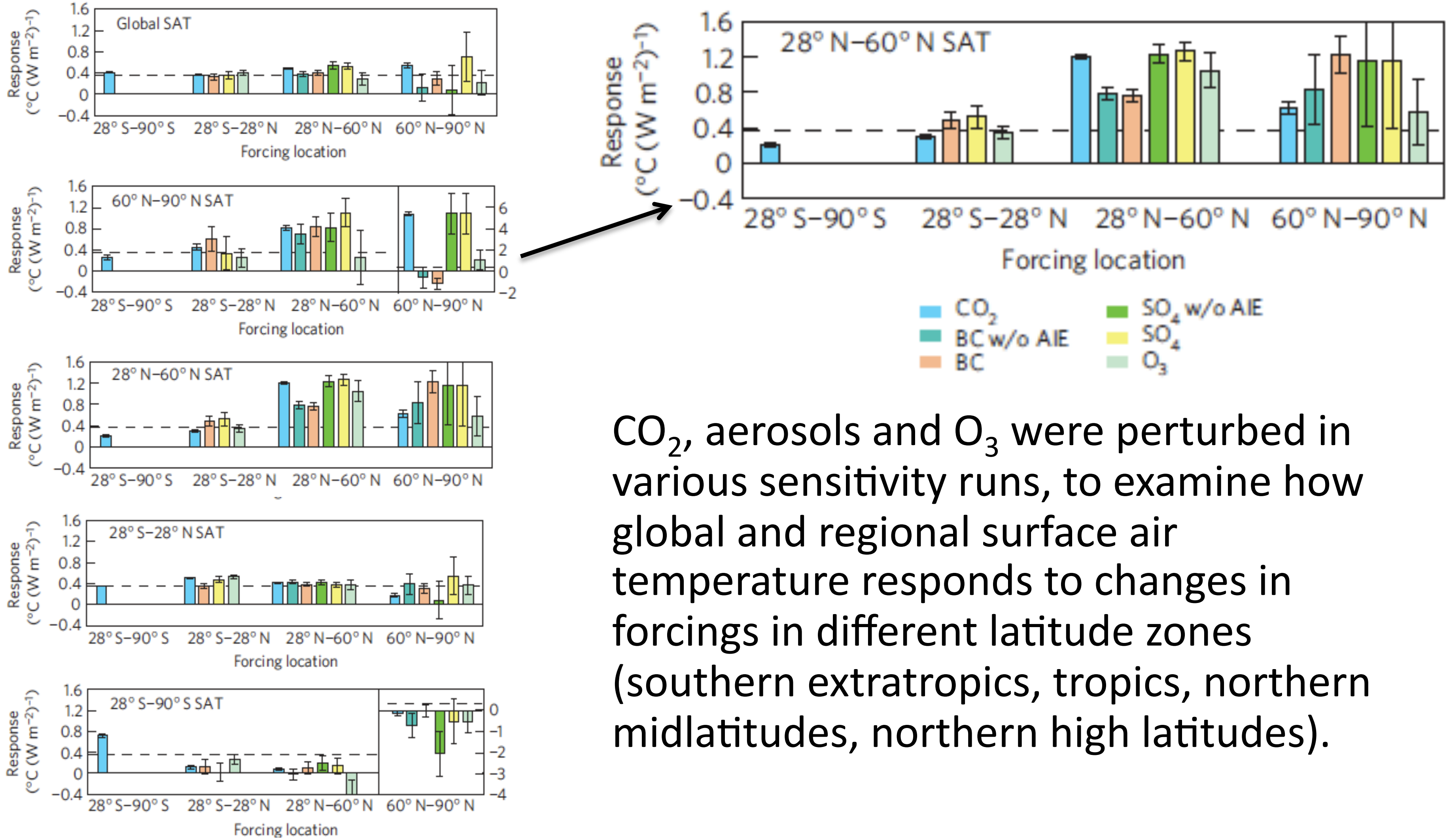
ECS: "Most likely between 2°C and 3.5°C".

TCR: "Most likely between 1°C and 3.5°C".

Q: But what about regional sensitivity and response?

A: Very little has been done to examine them..

Recent work providing regional forcing-response relationships



CO_2, aerosols and O_3 were perturbed in various sensitivity runs, to examine how global and regional surface air temperature responds to changes in forcings in different latitude zones (southern extratropics, tropics, northern midlatitudes, northern high latitudes).

Shindell and Faluvegi, *Nature Geosci.* (2009)

Calculation of the regional climate sensitivity parameter (or maybe it's not called like this)?

$$\lambda = \frac{\Delta T^{OBS}}{F\_W + F\_DI + F\_IN + F\_O3 + F\_LU}$$

λ : Climate sensitivity parameter.

ΔT^{OBS} : Observed temperature change.

F terms : Radiative forcings from various agents (W is from well mixed greenhouse gases, DI is from the aerosol direct effect, IN is from the aerosol indirect effect, O3 is from ozone and LU is from land use changes.

Adding the non-local forcings:

For latitudes north of 28° S:

$$\lambda_i^{LOC+NON\_LOC} = \Delta T_i^{OBS} /$$

$$\left(\frac{F\_W^{SE} \times r\_W_i^{SE} + F\_W^{TR} \times r\_W_i^{TR} + F\_W^{NM} \times r\_W_i^{NM} + F\_W^{NH} \times r\_W_i^{NH}}{r\_W_i^{SE} + r\_W_i^{TR} + r\_W_i^{NM} + r\_W_i^{NH}} + \right.$$

$$\frac{F\_DI^{TR} \times r\_DI_i^{TR} + F\_DI^{NM} \times r\_DI_i^{NML} + F\_DI^{NH} \times r\_DI_i^{NH}}{r\_DI_i^{TR} + r\_DI_i^{NM} + r\_DI_i^{NH}} +$$

$$\frac{F\_IN^{TR} \times r\_IN_i^{TR} + F\_IN^{NM} \times r\_IN_i^{NM} + F\_IN^{NH} \times r\_IN_i^{NH}}{r\_IN_i^{TR} + r\_IN_i^{NM} + r\_IN_i^{NH}} +$$

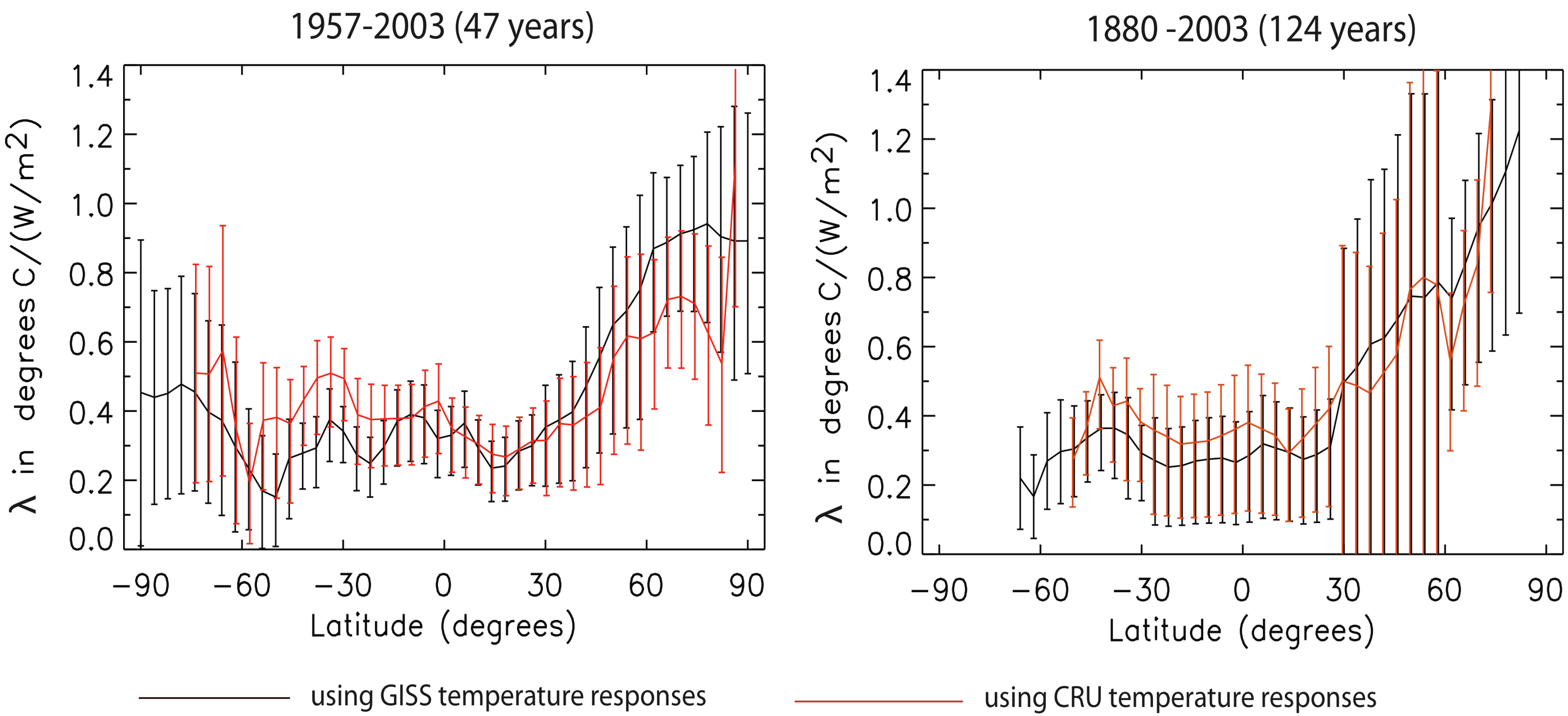
$$\left.\frac{F\_O3^{TR} \times r\_O3_i^{TR} + F\_O3^{NM} \times r\_O3_i^{NM} + F\_O3^{NH} \times r\_O3_i^{NH}}{r\_O3_i^{TR} + r\_O3_i^{NM} + r\_O3_i^{NH}} + F\_LU^{k}\right)$$

* What are the r terms?: They are weighting factors taken from the figure of Shindell and Faluvegi shown before.

What data did we use?

- We used 4 global surface temperature datasets: the GISS and the CRU data for 1957-2003 and 1880-2003.
- From these we calculated trends of the zonal mean temperature and eventually the linear response from the start year to the end year of the observations (also the 2-σ error).
- We also include the influence of internal variability as an addition to the uncertainty in ΔT.
- We used observed WMGHG and land use forcings and modeled ones for other forcing agents (aerosols, ozone). We applied the AR4 estimated 2-σ uncertainty to these values.
- We then calculated λ for all the latitude bands, using the complex equation of the previous page.
- Standard error propagation analysis gave us the overall uncertainty for λ, based on the uncertainties of the other parameters.

Results for all latitude bands:



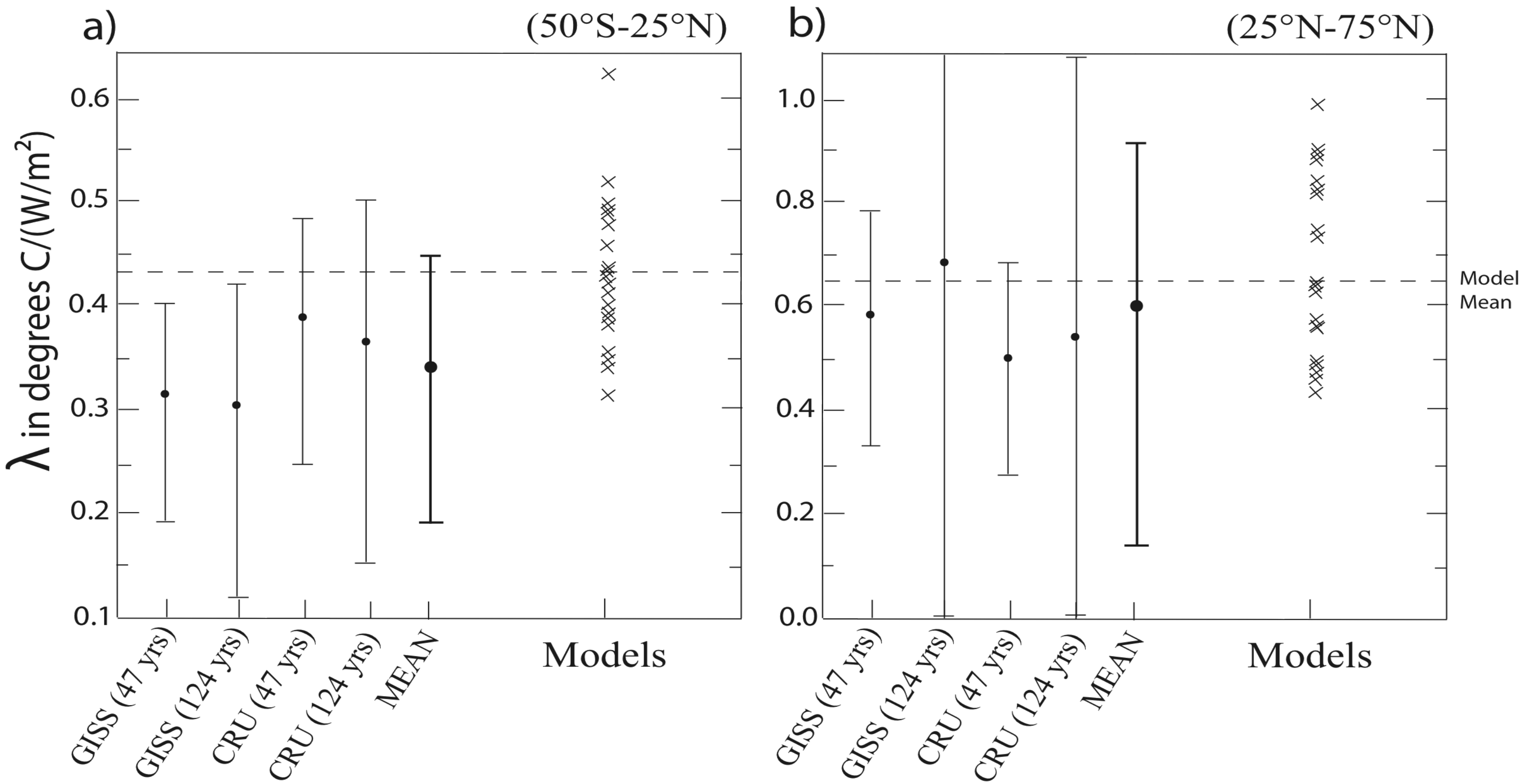
- λ is smallest in the tropics.
- Uncertainties are large, especially for the northern extratropics.
- However, there is a region where the estimates agree more, and where the error bars are smaller: 50°S-25°N where λ is 0.34°C/(W/m^2) (ranging from 0.25 to 0.4°C/(W/m^2)).

Also…

- The area weighted global mean λ calculated from our method is 0.39 °C/(W/m^2), ranging from 0.22 to 0.52°C/(W/m^2).
- TCR in AR4 was 1.76°C.
- If we take into account the 2xCO2 forcing that they estimated (3.80 W/m^2), their λ would have been 0.46°C/(W/m^2).
- This is larger than our estimate, but well within the uncertainty.

NEXT: We show λ values for the better constrained region (50°S-25°N) both from our estimates and from the CMIP3 models.

And how do our results compare with models?



- For the northern extratropics our estimate is very uncertain. For 50°S-25°N it is better constrained.
- The average of the models for the 50°S-25°N region is 25% higher than our estimate.

So, are the models too sensitive, at least in this region?

Not sure, but we went some steps further to shed some light on this:

- We calculated λ from the CMIP3 models that participated in the "Climate of the 20th Century" experiment.
- In observations, the average temperature change in 50°S-25°N is 0.57°C, while in the models it is 0.62°C, so there is only a 10% difference – does not explain the discrepancy.
- Could it be that the models ARE indeed too sensitive in this region, but the still capture the temperature change because they also overestimate e.g. the aerosol negative forcing?
- It need further investigation, but Kiehl et al. (2007) and Myhre (2009) help support this hypothesis.

Conclusions

- We present a new method for calculating regional climate sensitivity (or whatever it should be defined as) using observed temperature changes.
- This method takes into account both local and non-local forcings for a given region.
- We find that λ can be better constrained in a region between 50°S-25°N, although the uncertainty is still substantial.
- The CMIP3 models reveal a 25% larger sensitivity in this region.
- The fact that they capture the 20th century warming, although they may be too sensitive, may have to do with a significant aerosol forcing underestimate.

Future work

Several things, but here are some important ones:

- Examine how different the climate sensitivity is in the GISS model when using a) results from the 1%yr^{-1}, b) results from the Climate of the 20th Century experiment. The 1%yr^{-1} CO_2 forcings that we used here are obviously different than the "real ones", used for our λ calculation. So we may be introducing some bias when doing a comparison with the 1%yr^{-1} model runs.

- Improve our terminology?

Thanks!!

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